Defense Basic Research

NDIA: 6th Annual S&E Technology Conference

Presented by

Dr. Bill Berry
Acting Deputy Under Secretary of Defense
(Laboratories and Basic Sciences)

19 March 2005

Defense Basic Research

- ***Why do Basic Research in DoD?***
- ***Management of DoD Basic Research***
- ***Basic Research in context of Defense RDT&E***
- ***Services and DARPA's Basic Research Programs***
- ***Summary***

Main Purposes for Defense Basic Research

- ***Generate new knowledge and understanding as foundation for future defense technologies***
- ***Train scientists and engineers in key disciplines for defense needs***
- ***Sustain research infrastructure needed for continued performance of cutting-edge defense research***

DoD's Basic Research Program

Competitive, multifaceted program to enable revolutionary ideas

- University based, single investigators, broad areas
- In-house laboratories for "smart buyer" and "essential capabilities"
- Industry and services to exploit results

Flexible, balanced portfolio

- Long-term, mission orientation
- Engineering emphasis (at least 50 percent)
- Stable commitment to key capabilities (e.g., sensors)

Infrastructure support

- University personnel and students
- Laboratories (lean, modern, focused)

Planning and oversight

- Link to top-down elements (S&T Strategy, DTAP, JWSTP, DTOs)
- Basic Research Review
- Service reviews, peer and merit reviews

Basic Research is Focused in Areas Important to Defense

- ***Invest in broad base of DoD-relevant areas across scientific and engineering disciplines***

- ***Broad base is complemented by six Strategic Research Areas, some of most exciting areas with high potential for DoD benefit:***

Bioengineering Sciences
Human Performance Sciences
Information Dominance
Multifunction Materials
Nanoscience
Propulsion and Energetic Sciences

- ***Complements other Federal agency investments. For example, while DoD provides only about 6% of total Federal investment in basic research, it provides:***

75% of Federal basic research funding in electrical engineering
66% of funding in mechanical engineering
40% of funding in mathematics and computer science

Management of DoD Basic Research

- ***Basic Research Plan*** provides vision & strategy for planning & execution

- ***Three levels of*** DoD management ***oversight***
  - ***DSTAG*, Defense S&T Advisory Group**
    DDR&E's S&T executives for *major issues*
  - ***DBRAG* Defense Basic Research Advisory Group**
    Service and other research office senior managers provides leadership and oversight on *other cross-cutting issues*
  - ***SPGs Scientific Planning Groups***
    program managers *coordinate programs* across Services & DARPA

- ***Defense Basic Research Review*** — every two years, an external and multi- Agency panel reviews DoD research quality, relevance & emphases

- DoD Basic Research Office got ***OMB's highest "Effective" rating***

FY06 RDT&E Budget Request

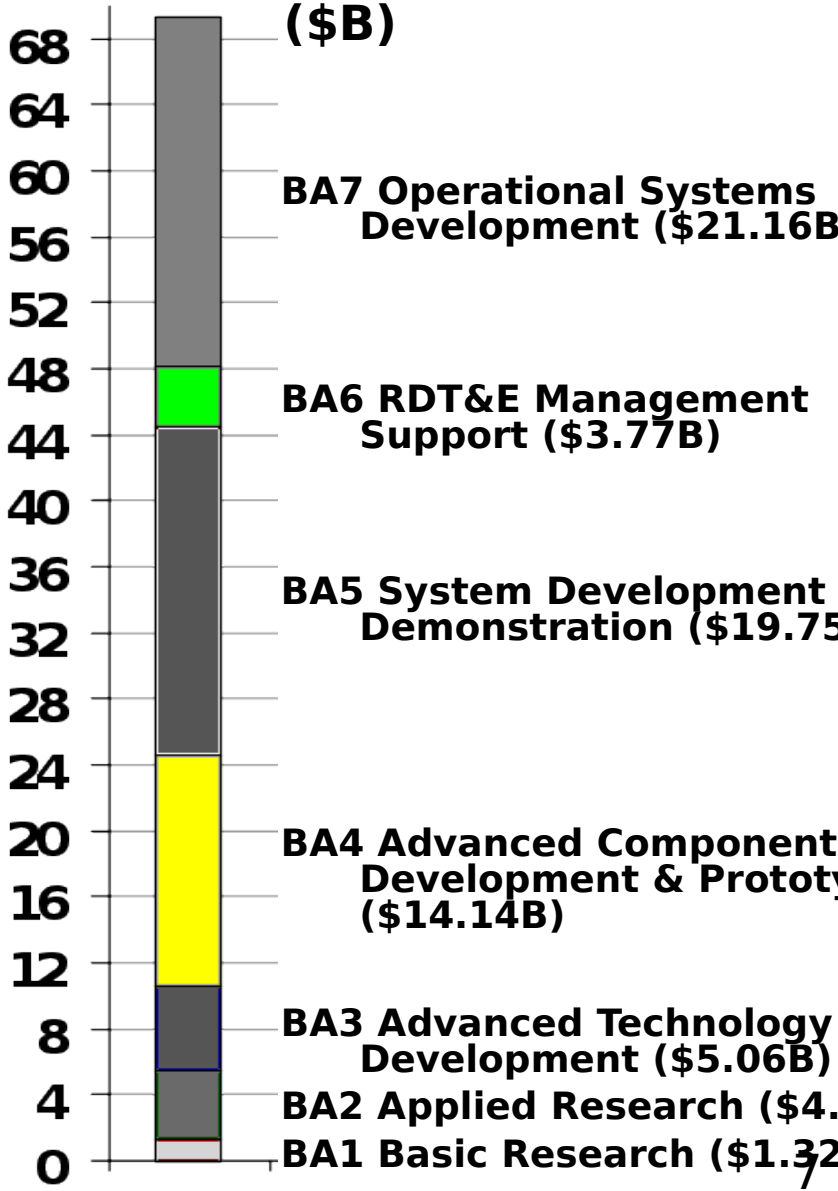
FY06 RDT&E request = $69.36B (Budget Activities 1-7)

(BA6 + BA7 = $24.93B)

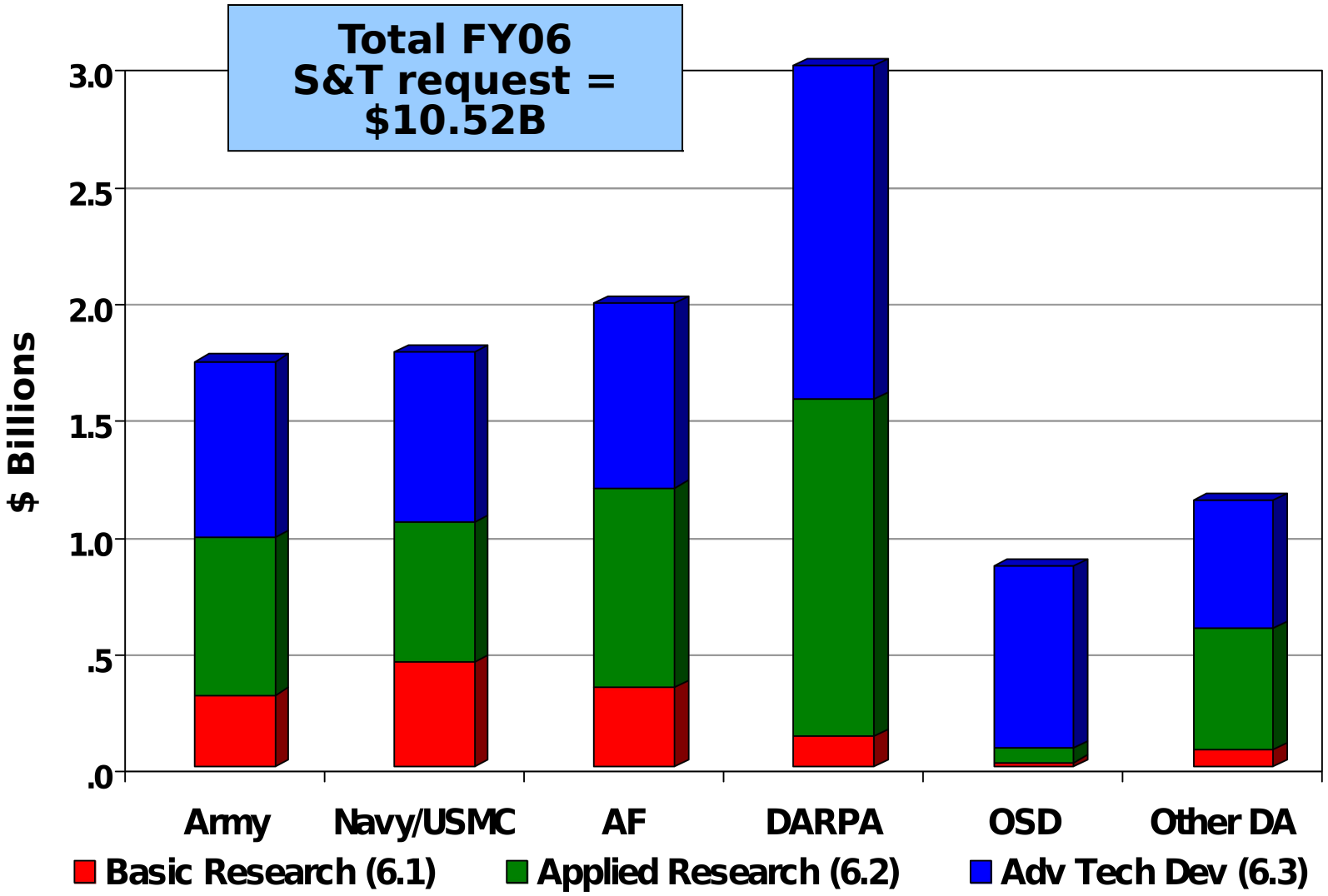
Development (BA4 + BA5 = $33.89B)

Science and Technology (BA1 + BA2 + BA3 = $10.52B)

15% of RDT&E



FY06 DoD S&T Budget Request

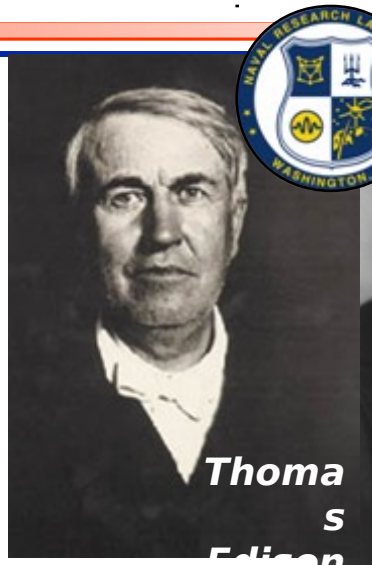


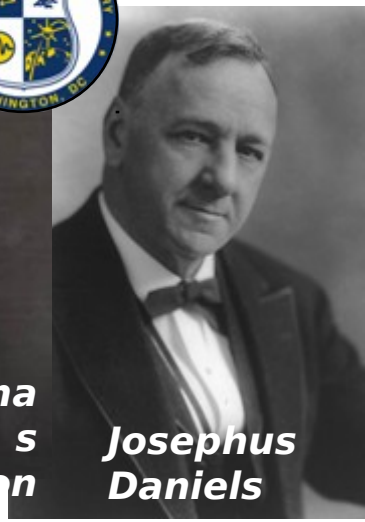
Source & Destination of Defense Basic Research Funding

←Source 86% of Defense Basic Research ($1.33B) is from Investments by Military Departments

Destination→
Performers of Defense Basic Research

Naval Research: Statutory Mission





Naval Research Laboratory *(Appropriations Act, 1916)*:

"[Conduct] exploratory and research work… necessary… for the benefit of Government service, including the construction, equipment, and operation of a laboratory…."

Office of Naval Research *(Public Law 588, 1946)*:

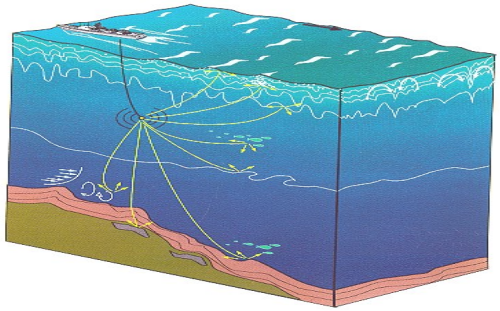
"… plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security…."

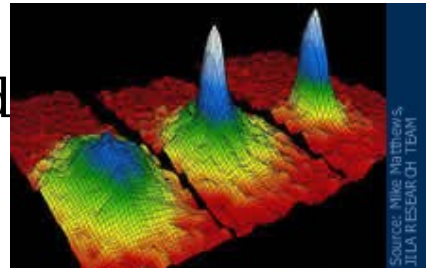
Transitioning S&T *(Defense Authorization Act, 2001)*:

"…manage the Navy's basic, applied, and advanced research to foster transition from science and technology to higher levels of research, development, test, and

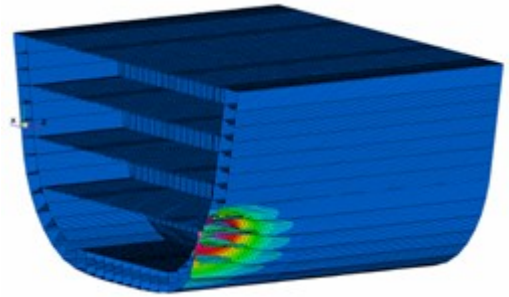
National Naval Responsibilities

- Naval environment is distinctive and complex
- Naval science and technology must maintain areas critical to ensuring Naval superiority:
  - –Robust U.S. research community
  - –Adequate pipeline of new scientists and engineers in Naval-unique disciplines
  - –Ensured future S&T products to Naval forces

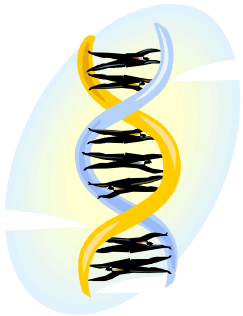




- *Ocean Acoustics*
- *Underwater Weaponry*
- *Naval Engineering*
- National Naval Responsibilities:



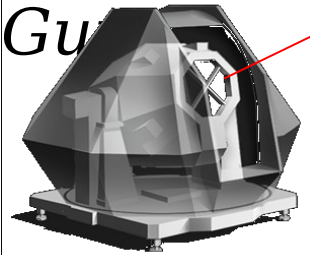
- *Undersea Medicine* *(consideration)*

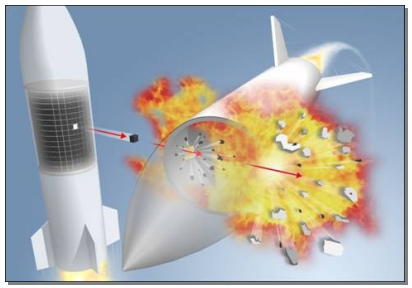


ONR Focus Areas

- **Global War on Terror**
  - *Emphasis on Counter IED*

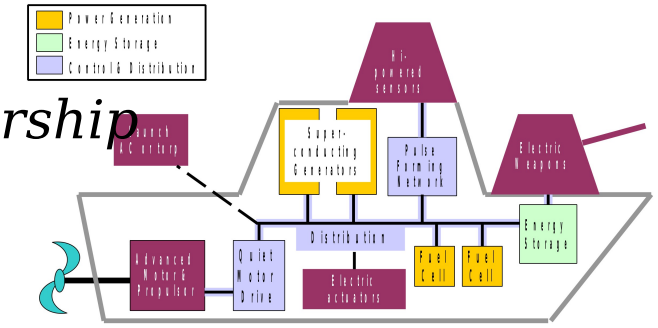
- **Directed Energy Weapons**
  - *Free Electron Laser & Rail Gu*





- **Advanced Energetics**
  - *Increased Energy Density*

- **Energy and Power**
  - *Enabling the All Electric Warship*



Countering the IED Threat
6.1 Basic Research for Long Term Solutions

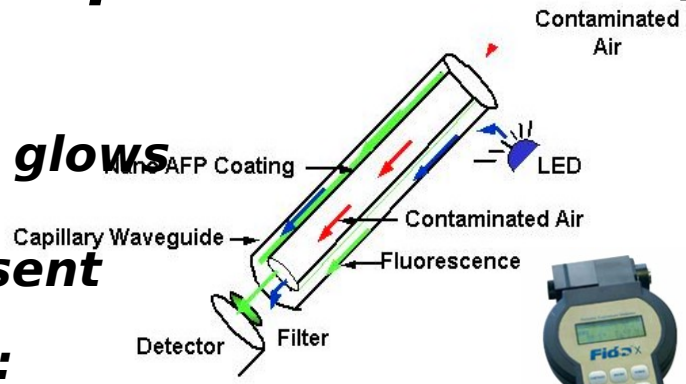
- Strategy
  - Long term basic and applied research addressing foundations of current and future IED problem
  - Systems approach attacking each step in the engagement
  - Focus on Detect, Defeat, Destroy
  - Exploit sensor, chemistry/materials, and EW expertise
- Approach
  - A sustained investment
    - focused counter-IED research program -“manhattan-like project”
    - detection of threat & advanced long range destruction technologies

Proposal Processes -- Army 6.1 Program

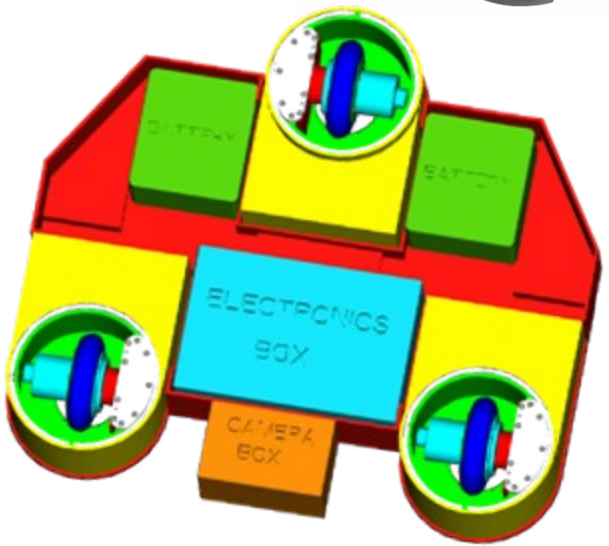
- ***University Single Investigators***
  - ***Grants to extend boundaries of fundamental knowledge***
  - ***Annual BAA, peer review process; 2-3 year cycle per grant; ~ 100***
- ***University Centers***
  - ***University-lead, focused initiatives***
  - ***Competitive Contract; 3-5 year duration; $1-2M/year efforts***
- ***Collaborative Technology Alliances***
  - ***Industry-led partnership with Army laboratories and academia***
  - ***Competitive Cooperative Agreements; 5-8 year duration; $5- 8M/***
- ***Paradigm Shifting Transformational Centers***
  - ***OSD approved University Affiliated Research Centers (UARCs)***
  - ***Sole Source or Competitive Contract; 5-8 year duration; $5-10M/y***
- ***Army Unique Laboratory Research***
  - ***ILIR-Lab Director funds promising research; HQDA level peer revi***
  - ***ARI, COE, and MRMC – Annual BAA, peer review process***
  - ***ARL, COE and MRMC – Internal process for program selection & fo***
    Periodic peer review of program quality

Detection/Inspection of Truck Bombs and Improvised Explosive Devices (IEDs)

- **The Science: Amplifying Fluorescent Polymer (AFP) developed by ISN normally glows green, but quenches when TNT is present**
- **The Detection Opportunity: Explosives leave invisible traces, which generate vapors that the AFP in Fido can sniff and detect**
- **ODIS is a developmental robotic platform for on-road and off-road inspection at vehicle check-points or anywhere high maneuverability is required**
- **Fido sensor is being integrated onto ODIS platform to provide unique capability to inspect for and detect truck bombs and IEDs**



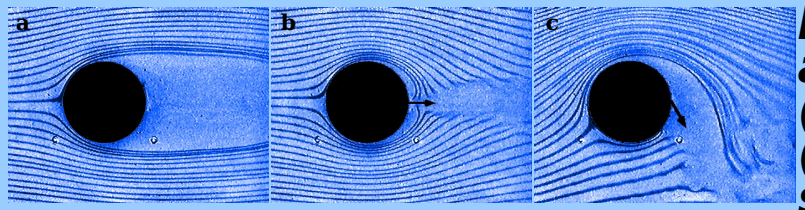
Fido



ODIS

Micro Active Flow Control

Small-scale blowing of jets of air at precisely the right spatial and temporal locations can control large scale flow-fields



Impact: aerodynamic drag (b) & lift forces (c) can be significantly modified by small

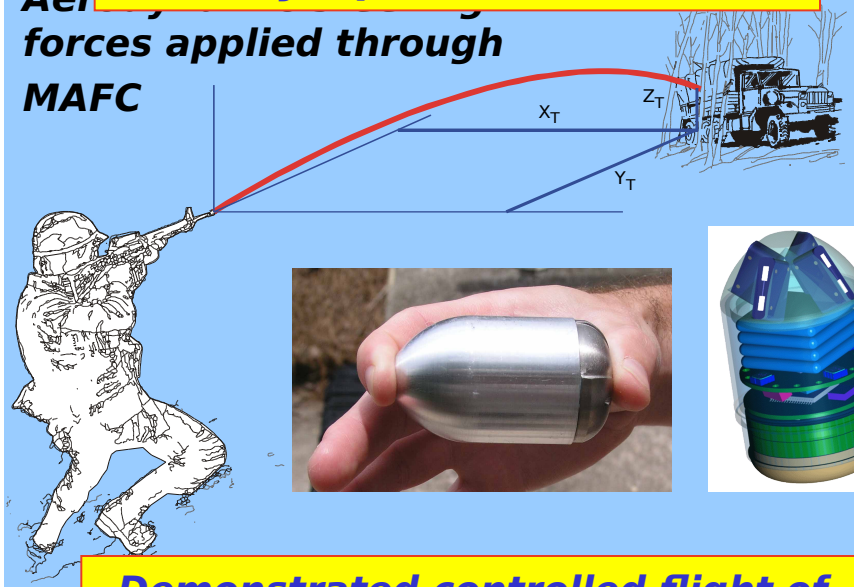
- ***Applications: guided munitions, enhanced performance VTOL aircraft, turbine engine surge and stall control***
- ***Concept developed in research originally performed at U of Arizona, Tel Aviv U, Georgia Tech***
- ***Program management/funding by ARO and DAR***

Tiltrotor Download Alleviation

Demonstrated 10% net download allevi-ation, which would yield a significantly enhanced payload (1000 lbs) or mission range (77% increase) for the V-22

SCORPION – (Self Correcting Projectile for Infantry Operation)

Aer… forces applied through MAFC



Demonstrated controlled flight of a 40 mm projectile with steering forces sufficient to compensate for muzzle velocity dispersion

"Liquid Armor" Concept

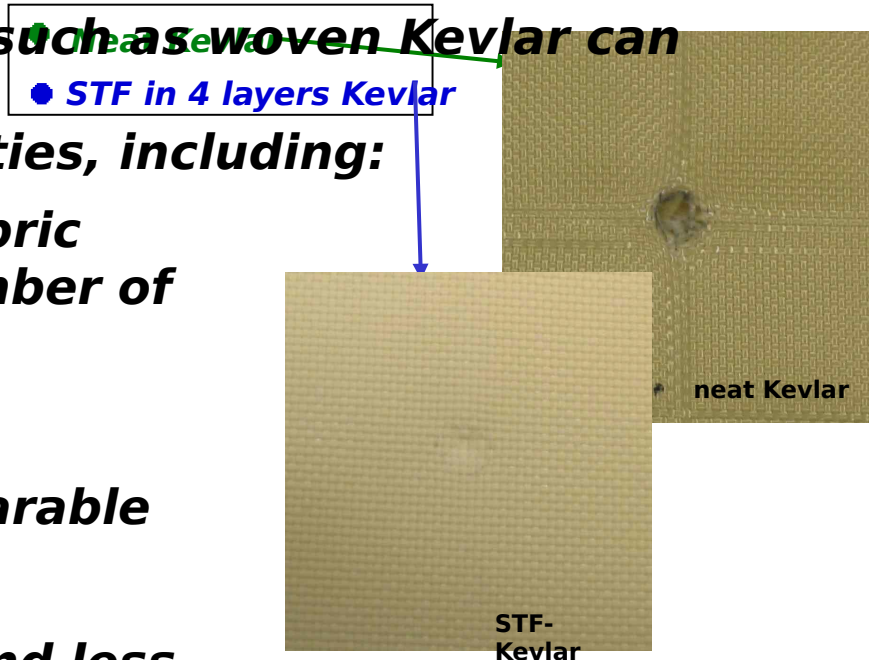
Objective: Provide a compact, flexible armor material

- ***Shear thickening fluids (STFs):*** ***Materials (nanoparticles of silica suspended in polyethylene glycol) which are flowable at low deformation rates but solid-like at high deformation rates (nanoparticles compress into rigid mass)***

- ***Adding STFs to ballistic fabrics such as woven Kevlar can dramatically improve their protective properties, including:***

STF-Kevlar vs. Neat Kevlar:

- ***Reduced areal density (high fabric loading)***
- ***Equivalent ballistic resistance***
- ***Reduced number of fabric layers (high STF loading)***
- ***Fewer layers required for comparable ballistic properties***
- ***Significantly higher flexibility and less bulk***

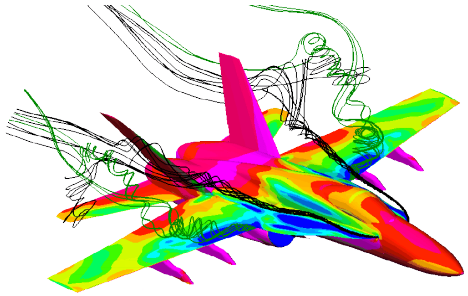


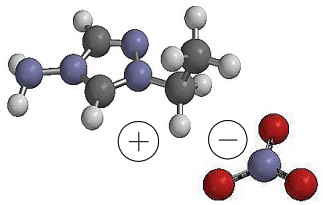
Comparison of neat Kevlar and STF-Kevlar after ballistic impact

Air Force Office of Scientific Research (AFOSR)

- **Single Manager for Basic Research Addressing Air Force Ne**
  - **Component of the Air Force Research Laboratory (AFRL)**

- **Physics**
- **Solid Mechanics and Structures**
- **Chemistry**
- **Mathematics and Computing Sciences**
- **Electronics**
- **Fluid Mechanics**
- **Propulsion**
- **Space and Information Sciences**
- **Biological Sciences**
- **Human Performance**





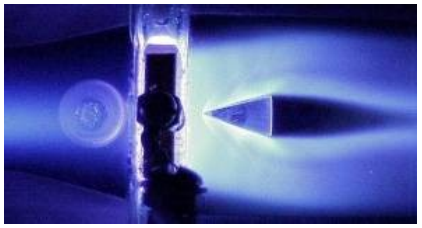
Creating Revolutionary Scientific Breakthroughs for the Air

AFOSR Funding
(FY2004)

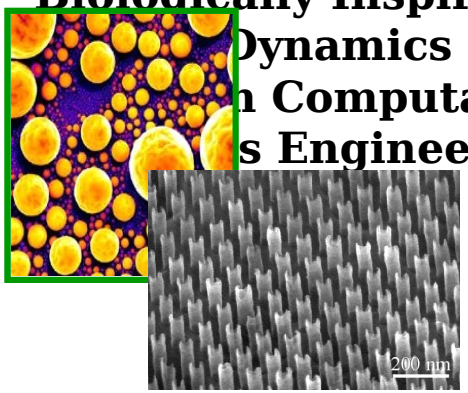
- **Air Force Core Basic Research Program ($205M)**
  - **Over 800 Grants to Over 180 Universities (~60%)**
  - **AFRL and Other Air Force Organizations (~30%)**
  - **Industry and Others (~10%)**
- **University Research Initiatives ($104M)**
  - **Multidisciplinary University Research Initiatives**
  - **Defense University Research Instrumentation Program**
  - **National Defense Scientists & Engineers Fellowships**
- **Other Agency Funds (~$85M)**
  - **DARPA**
  - **Small Business Technology Transfer (STTR) Program**
  - **Others**

AFOR is the Sole Manger of Air Force Basic Research

AFOSR Emphasis Areas



Themes **Cooperative Control · Plasma Dynamics· Miniaturization Science · Biologically Inspired Concepts · Dynamics · Type II n Computation · s Engineering**



Nanotechnology **Multispectral Detector Arrays · Chip Scale Optical Networks · Compact Power for Space · Nanoenergetics · Nanomaterials for Structures**

Information Dominance **Human Decision Making · Adversarial Modeling· Information Assurance · Information Fusion · Information Operations · Command & Control Infosphere · Transformational Communications**

Polynitrogen Chemistry

New rocket fuel?

Polynitrogen compounds could pack double the punch of existing space propellants.

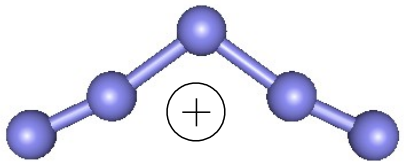
Revolutionary synthesis of the N_5^+ cation and production of polymeric nitrogen have opened up new field of polynitrogen compounds for all-nitrogen propellants.

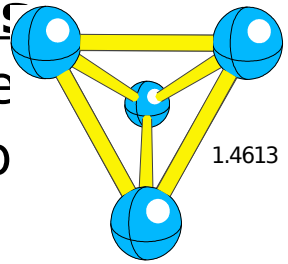
Advantages

- Substantially reduce cost of space delivery
- Major safety improvements
- Environmentally benign/reduced signature

Applications

- Space lift - (main booste
- L ɔrop
- S





Biologically Inspired Guidance & Control

NextFrontiers

INVENTING THE FUTURE

Even the most important new ideas can seem silly at first, or irrelevant or downright dangerous. (You mean that thing can fly?) How do you tell which ones are worthy? The best way is to just give them a try. Ten innovations that may change the way we live.

Ten innovations that may change the way we live.

BY MICHAEL HASTINGS

BRYANT LINARES has one heck of a secret family r... how to make ... class diamond... Seven years ago his fathe... Robert, produced a diam... a high-pressure chamber... bon gas and dropped it in... acid solution to clean it o... When he returned the ne... morning, he expected to ... the usual yellow stone—a... artificial diamond of som... industry, perhaps, but no... stuff of dreams. At first th... didn't seem to be any sto... Then he saw, at the botto... the beaker, so clear it was... invisible, a perfect quarte... crystal of pure carbon. "It was the eureka moment," says Bryant. His father had managed what many scientists had given nothing new—industry started making them in the 1950s, and each year about 80 tons of low-... them. Scientists are most excited about the prospect of making ... they create. Because silicon, the main component of semiconductors, breaks down at about

2

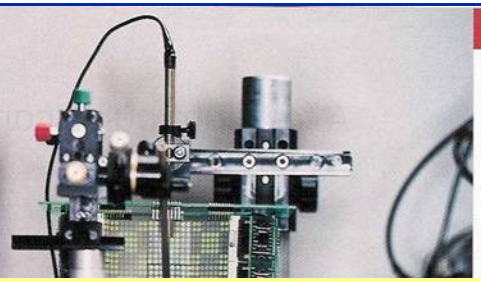
What A Fly Knows

BY JERRY ADLER

SOMETIMES, AT THE ... lecture, Michael Dickinson will set a wineglass of vinegar or whisky down on the edge of his lectern. Dickinson, a professor of bioengineering at Caltech, is one of the world's experts on the flight mechanics of fruit flies. He has spent years fitting them with tiny harnesses, rotating them in a virtual-reality chamber, filming their wings with ultrahigh-speed cameras to catch them as they change direction in one fifth the duration of an eye blink. He has modeled their aerodynamics with an oversize robot fly whose wings flap mechani-...

FLIGHT SIMULATOR: Fruit fly (inset) tracks odors in Dickinson's virtual-reality chamber

Dickinson is in effect reverse engineering a living creature, taking it apart to see how it was built and how it functions, with the goal of someday replicating at least part of its behavior.



... suppose we could deploy a fleet of drone aircraft equipped like mosquitoes, with sensitive detectors

As he ... ow ... med ... edge? ... he ... d of ... are. ... ng ... lity ... s ... inson ... ...

But now ... pose we could deploy a fleet of drone aircraft equipped, like mosquitoes, with sensitive detectors for carbon dioxide. Could we build such devices, and make them cheap and robust enough to cover a large territory? In part, ... is a software problem: ... duct a search in the ... dimensions, ... and unpredictable obstacles. Insects solve it with a brain—in the case of fruit flies—the size of a poppy seed, containing perhaps 300,000 neurons. The average human has 100 billion.

To investigate how they do it, Dickinson has built a miniature fly world, a cylindrical cage about a meter across and high, with varying obstacles and background patterns projected on the walls, and electronic cameras recording the fly's movement at speeds up to 6,000 frames per second. The fly's task is to find an odor source on the floor of the apparatus. "The animal wants to track the plume to its source. So the first thing it has to do is orient upwind. But the plume is snaking around, the fly may have to avoid a visual obstacle, so there's a good chance it will lose it. What does it do then?" Dickinson is in effect reverse-engineering a living creature, taking it apart to see how it was built and how it functions, with the goal of someday replicating at least part of its behavior. We are far from being able to build machines that can walk upside down or hover like an insect, at least on those size scales, he says. But it would be nice to be able to think like them. ■

FROM TOP: PHOTOGRAPH BY MONA DAVIDSON FOR NEWSWEEK (2); COURTESY OF MICHAEL DICKINSON—PRINCETON UNIVERSITY

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3

How to Program A Cell

BY CARL ZIMMER

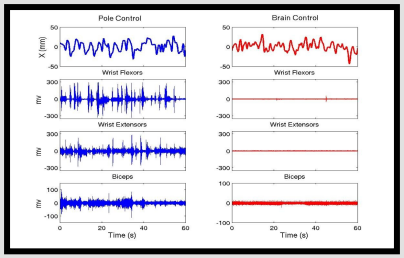
A LOT OF TODAY'S engineers got their start as kids playing with electronics kits, wiring together resistors or capacitors. Depending on how you put the pieces together, you could build a simple switch or make bulbs blink like a movie marquee.

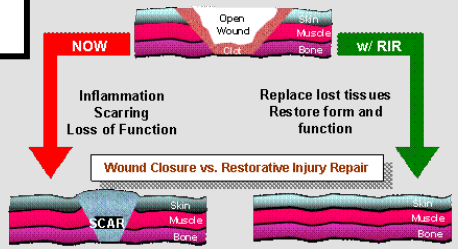
WIRED: Telling cells how to behave

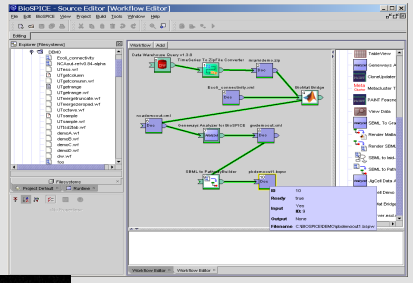
Basic Research in Biology
BLS-01

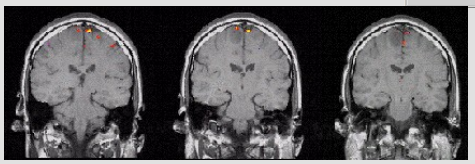
DEFENSE SCIENCES OFFICE

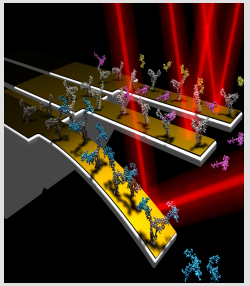
- **Human Assisted Neural Devices**
  - Understanding the Language of the Brain Enabling Technology for Revolutionizing Control of Prosthetics
- **Biological Adaptation, Assembly and Manufacture**
  - Exploit the unique response, adaptability and fault tolerance of biological systems
- **Nanostructure in Biology**
  - Apply advances in nanotechnology to understand and exploit the nanostructure features of biology
- **BioComputation**
  - Application of computation and design tools to understand biology of interest to DoD
- **Bio Interfaces**
  - Understand and Exploit the Intersection Biology with the Physical and Mathematical Sciences
- **Simulation of Bio-Molecular Microsystems**
  - Develop phenomenological models, scaling laws and design rules for Bio-Microdevices.







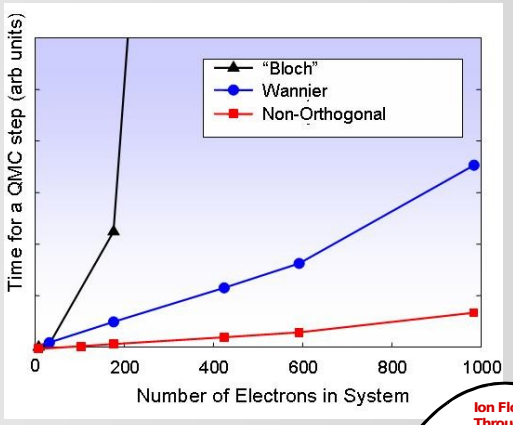


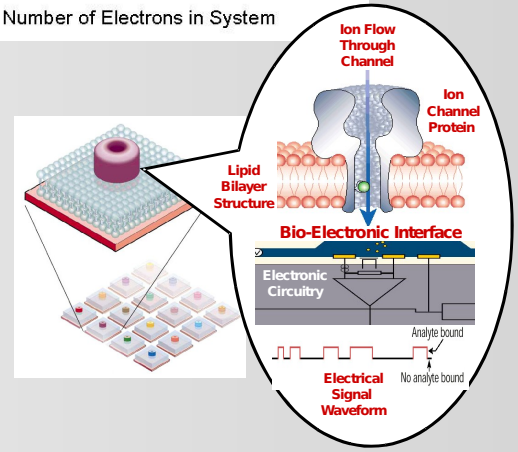


Basic Research in Biology BLS-01

DEFENSE SCIENCES OFFICE

- **Nanoscale/Bio-molecular and MetaMaterials**
  - Control of nanoscale and biological structure for materials and devices
- **Engineered Bio-molecular Nano-Devices and Microsystems**
  - Technologies to enable high speed transduction of biological signals into electrical signals
- **Spin Dependent Materials and Devices**
  - Use of electronic spin for ultrasecure, ultrafast electronic and communication devices

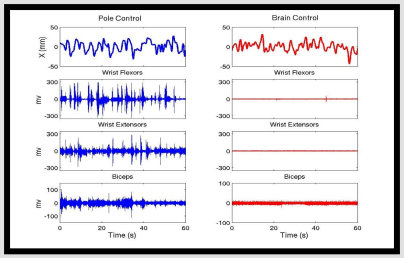


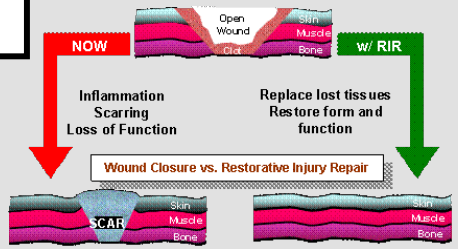


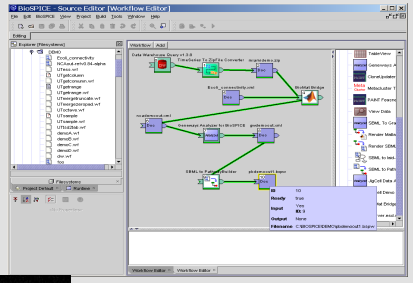
Basic Research in Biology
BLS-01

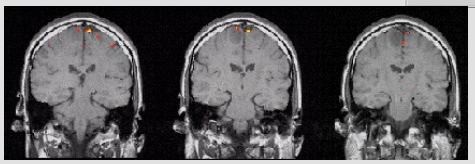
DEFENSE SCIENCES OFFICE

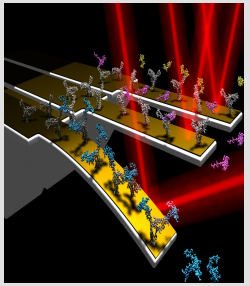
- **Human Assisted Neural Devices**
  - Understanding the Language of the Brain Enabling Technology for Revolutionizing Control of Prosthetics
- **Biological Adaptation, Assembly and Manufacture**
  - Exploit the unique response, adaptability and fault tolerance of biological systems
- **Nanostructure in Biology**
  - Apply advances in nanotechnology to understand and exploit the nanostructure features of biology
- **BioComputation**
  - Application of computation and design tools to understand biology of interest to DoD
- **Bio Interfaces**
  - Understand and Exploit the Intersection Biology with the Physical and Mathematical Sciences
- **Simulation of Bio-Molecular Microsystems**
  - Develop phenomenological models, scaling laws and design rules for Bio-Microdevices.



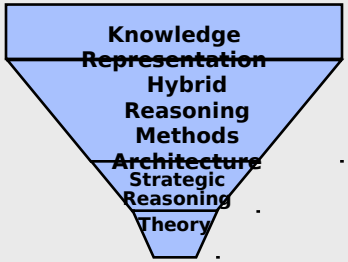


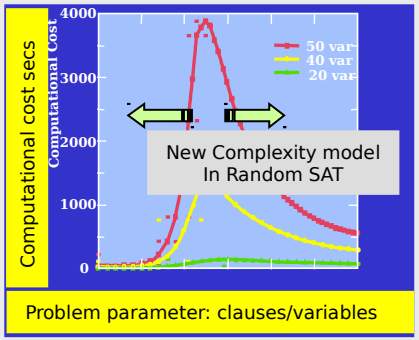


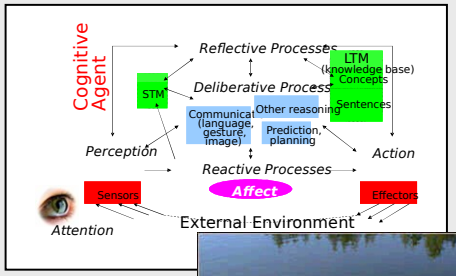




Computer Exploitation and Human Collaboration







Goal: develop information processing technologies to enable users to interact with computers in an intuitive fashion, and enable collaborations as well as intelligent exchange of information in a seamless manner

Technical Challenges

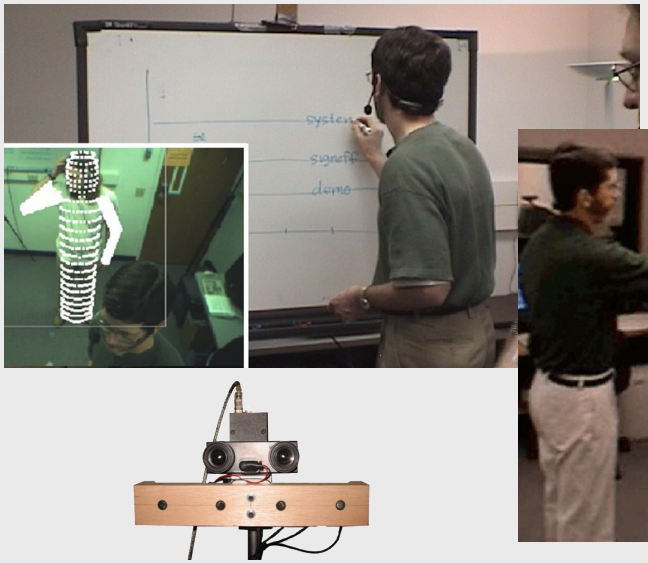
- Practical inferential "deep" reasoning within the complexity of the real world
- Integrated hybrid reasoning tools to aid in decision making within a multi-player context
- Episodic information learning from experience and the application of that information
- Natural communication modalities to maximize effectiveness of the human computer interface
- Selective filtering of salient information within the mission context

Technical Approach

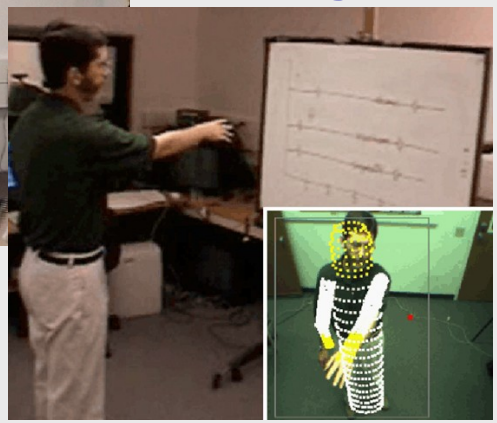
- Develop dynamic hybrid reasoning architectures addressing complexity in propositional inference
- Use insights from mathematical game theory to develop tools for strategic reasoning
- Modify software and hardware based on human perceptual processing models and neuroscience resulting in the extraction of salient information and enhanced human performance
- Conduct experiments to understand natural multimodal communication patterns in military contexts and develop adaptive processing techniques well suited to natural communication settings

Performers: SRI International; UC Berkeley; Cornell Univ; Naval Health Research Center; NAWC AD; BMH Inc.; and Carnegie Mellon Univ

Computer Exploitation and Human Collaboration Accomplishments

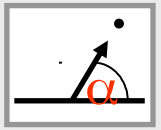


Multimodal Dialogue



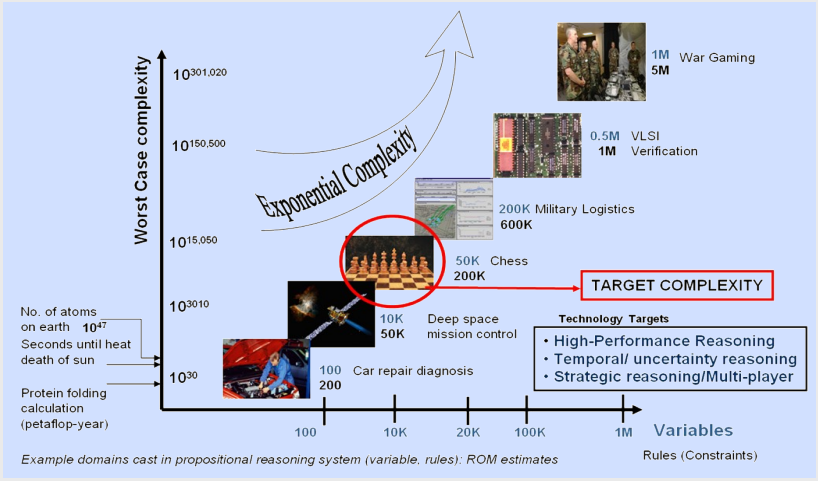
- New algorithms developed to locate people in meeting room and track where they are looking

- New direction of arrival algorithms discovered for determining where sound is coming from



- New algorithms developed for associated audio with correct portion of video

Reasoning

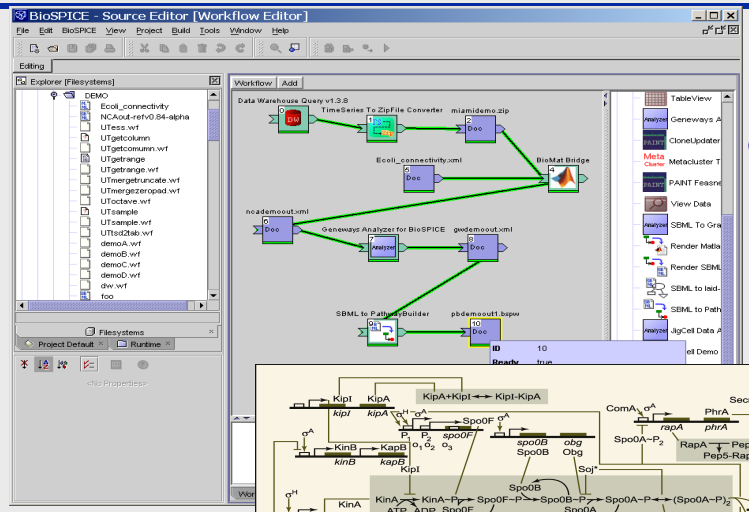


- Major step towards high-performance reasoning implemented: Developed new representations (Quantified Boolean Formulae) that speed up inference by 5 orders of magnitude
- Temporal reasoning under uncertainty: Implemented exact and approximate dynamic Bayesian networks that can scale to 1K-variable partially observed systems. Demonstrated Kriegspiel chess challenge problems (Program target 80% solution for problems with $10^{3,010}$ cases)
- Defined and implemented multi-agent reasoning in multi-player environments: Developed algorithms based on game theory for a variety of game reasoning scenarios

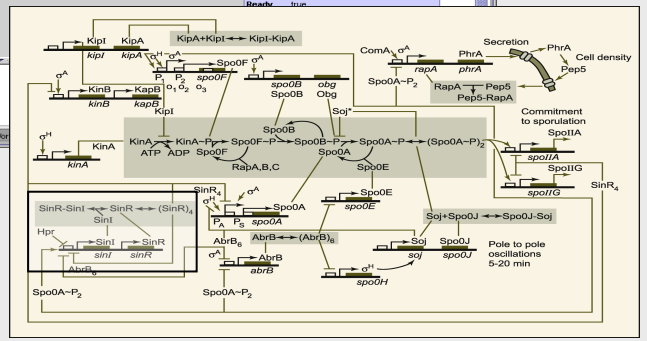
BioComputational Systems

Application of computation and design tools to understand biology of interest to DoD

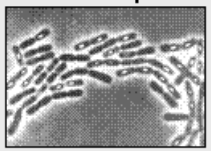
- **Computational modeling of biology**
  - Understanding pathogen/host interactions
  - Predicting early markers of disease
  - Understanding of emerging threats
- **Bio-SPICE computational tools**
  - Tools for modeling and analysis
    - Behavior of complex spatio-temporal networks
  - Tools for fast, robust simulation of hundreds of Intra-Cell Processes
- **Extensive model of sporulation developed for *Bacillus subtilis***
- **New molecular controls for cell division identified and validated**
  - Potential new methods for wound healing, nerve regeneration, and bacterial growth control
- **Preliminary model developed for pathways (apoptosis) triggered by bio-agents**
  - Collaboration with Walter Reed Army Medical Research) to identify markers for early detection
- **Plans: Extend models to support complex behavior of tissue, organs, and systems biology**
- **Develop scalable and fast methods for knowledge formation, extraction, and modeling**



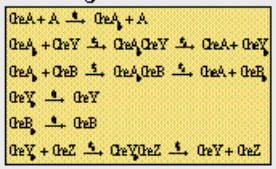
Bio-SPICE dashboard supports an extensible architecture



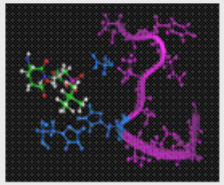
Genomic, clinical, and epidemiological Data across species and disease



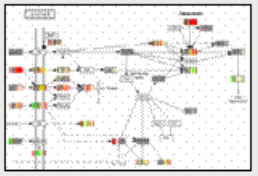
Biochemical, biophysical knowledge



Molecular structure data



Molecular interaction data



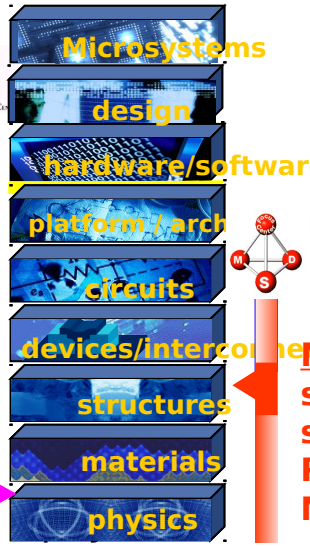
Deep and rapid knowledge formation
From disparate data for DoD biology

Microsystems Technology Office
Basic Research

GSRC- Centered on Systems:
- Hetero Design
- Soft Systems

C2S2 - Mostly Circuits:
- Analog/Mixed Signal
- Heterogeneous Circuits
- Post-CMOS circuits

FENA - Post-CMOS Research in Nano materials /devices.

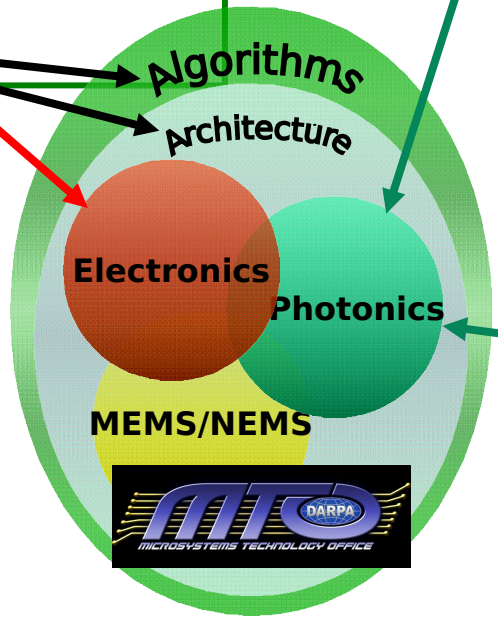


interconnect focus center

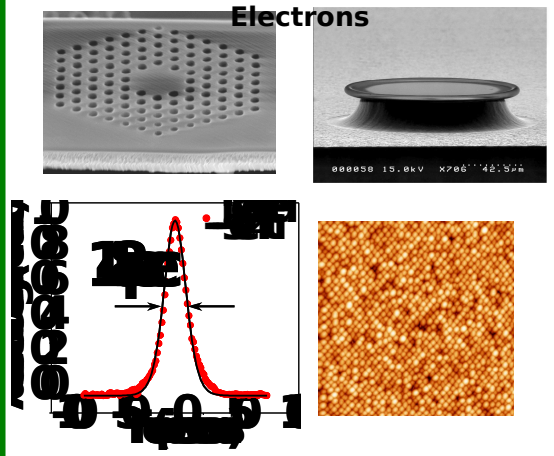
IFC - Nano wires; Expanded Opto-electronics, Photonics

MSD - Ultimate-scale CMOS structures; Post-CMOS Materials

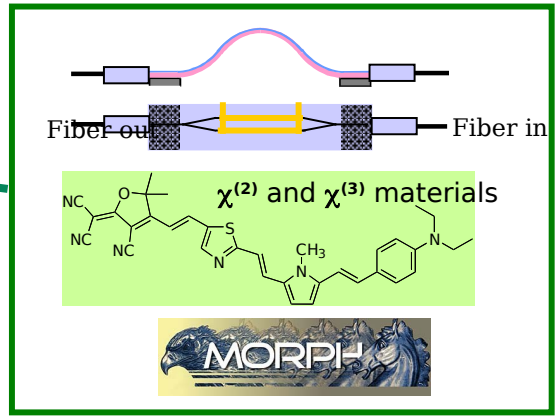
Focused Research Center Program



Spatial, Temporal, and Spectral Confinement of Photons and Electrons



University Photonics Research Centers



Super Molecular Photonics Research

Defense Basic Research

- Fundamental, long-term
- Multifaceted
- Broad Based and Strategic
- "Effective" in
  - Generating new knowledge
  - Training new Scientists/Engineers
  - Sustaining research infrastructure
- Enables novel technical options/capabilities

End

- Dr. William O. (Bill) Berry
- (703) 692-4592
- William.berry@osd.mil
- http://www.dod.mil/ddre/mainpage.htm